PB86-101144

Prevalence of Persistent Cough and Phlegm in Young Adults in Relation to Long-Term Ambient Sulfur Oxide Exposure

(U.S.) Health Effects Research Lab.
Research Triangle Park, NC

1985

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RI PB86-101144
EPA/600/J-85/159		

4. TITLE AND SUBTITLE
Prevalence Of Persistent Cough and Phelgm In Relation To Long-term Ambient Sulfur Oxide Exposure (Journal Version)

5. REPORT DATE
1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Robert Chapman, Dorothy Calafiore, Victor Hasselblad

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Health Effects Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

10. PROGRAM ELEMENT NO.
A119

11. CONTRACT/GRANT NO.
Intramural task

12. SPONSORING AGENCY NAME AND ADDRESS
same as #9

micrograms per cu.m.

13. TYPE OF REPORT AND PERIOD COVERED
Scientific Journal Article

14. SPONSORING AGENCY CODE
EPA-600/11

15. SUPPLEMENTARY NOTES
Published In: American Review of Respiratory Disease 132(2): 261-267, Aug. 1985

16. ABSTRACT

In early 1976, a survey of persistent cough and phlegm (PCP) prevalence was conducted in 5623 young adults in four Utah communities. Over the previous five years, community specific mean sulfur dioxide levels had been 11, 18, 36, and 115 micrograms per cubic meter (ug/m3). Corresponding mean suspended sulfate levels had been 5, 7, 8, and 14 ug/m3. No intercommunity exposure gradient of total suspended particulates or suspended nitrates was observed. in mothers, PCP prevalence among non-smokers was 4.2% in the high-exposure community and about 2.0% in all other communities. In smoking mothers, PCP prevalence was 21.8% in the high-exposure community and about 15.0% elsewhere. In fathers, PCP prevalence among non-smokers was about 8.0% in the high-exposure community and averaged about 3.0% elsewhere. In smoking fathers, PCP prevalence was less strongly associated with sulfur oxide exposure. PCP prevalence rates estimated in a categorical logistic regression model were qualitatively consistent with the prevalences presented above. The results of this survey were similar to those of a similar survey conducted in 1970. These results disclose an association of PCP prevalence with ambient sulfur oxide exposure, stronger in mothers than fathers, stronger in non- and ex-smokers than smokers, and stronger in 1970 than 1976.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	8
	20. SECURITY CLASS *(This page)*	22. PRICE
	UNCLASSIFIED	

EPA/600/J-85/159
JOURNAL ARTICLE

Prevalence of Persistent Cough and Phlegm in Young Adults in Relation to Long-term Ambient Sulfur Oxide Exposure[1,2]

ROBERT S. CHAPMAN, DOROTHY C. CALAFIORE, and VICTOR HASSELBLAD

SUMMARY In early 1976, a survey of persistent cough and phlegm (PCP) prevalence was conducted in 5,623 young adults in 4 Utah communities. Over the previous 5 years, community-specific mean sulfur dioxide levels had been 11, 18, 36, and 115 $\mu g/m^3$. Corresponding mean suspended sulfate levels had been 5, 7, 8, and 14 $\mu g/m^3$. No intercommunity exposure gradient of total suspended particulates or suspended nitrates was observed. In nonsmoking mothers, PCP prevalence was 4.2% in the high-exposure community and approximately 2.0% in all other communities. In smoking mothers, PCP prevalence was 21.8% in the high-exposure community and approximately 15.0% elsewhere. In nonsmoking fathers, PCP prevalence was 8.0% in the high-exposure community and averaged 3.0% elsewhere. In smoking fathers, PCP prevalence was less strongly associated with ambient sulfur oxide exposure. Intercommunity prevalence differences in smoking and nonsmoking mothers, and in nonsmoking fathers, were significant at alpha = 0.05. A categorical logistic regression model, testing simultaneously for effects of community and several covariates on PCP prevalence, yielded similar results. The results of this survey were similar to those of a similar survey conducted in Utah in 1970 and to those of other surveys. These results disclose an association of PCP prevalence with ambient sulfur oxide exposure, stronger in mothers than in fathers, stronger in nonsmokers and ex-smokers than in smokers, and stronger in 1970 than 1976.

AM REV RESPIR DIS 1985; 132:261-267

Introduction

It has been well documented that exposure to very high ambient levels of sulfur oxide air pollution, accompanied by similarly high suspended particulate levels, promotes severe health effects in humans (1, 2). However, the extent to which exposure to relatively low sulfur oxide concentrations affects human health is not yet clearly understood, particularly when these concentrations are not accompanied by high particulate levels. Recent evidence suggests that the lung function of persons with hyperreactive airways is more responsive to short-term experimental sulfur dioxide exposure than is that of the general population (3, 4). The weight of evidence also suggests an association of persistent cough and phlegm (PCP) prevalence in young adults with long-term exposure to sulfur oxide air pollution (sulfur dioxide and suspended particulate sulfates) (5–7). To test this association further, the U.S. Environmental Protection Agency (EPA) conducted a prevalence survey in early 1976 in 4 Utah communities selected to exhibit a gradient of long-term exposure to ambient sulfur oxides, but not to total suspended particulates or suspended particulate nitrates. Biomedical data were collected through a contract with the Utah State Department of Health. This survey incorporated methodologic improvements over previous prevalence surveys. Its results were also amenable to categorical logistic regression analysis, which to our knowledge has not been applied previously in published cross-sectional studies of air pollution health effects. The results of the 1976 survey are presented here. These results are also briefly compared with those of a similar survey conducted in 1970 in the same communities (5).

Methods

The survey was conducted during February and March 1976 in 4 Utah communities; Ogden, Salt Lake City, Kearns, and Magna. The latter 3 communities are in the Salt Lake Valley, which is also the location of a large copper smelter, the main source of sulfur oxide emissions in the study area. Magna, Kearns, and Salt Lake City lie, respectively, about 5 miles southeast, 8 miles southeast, and 13 miles east of the smelter. Ogden, at the foothills of the Wasatch Range, lies about 38 miles north of the smelter. In view of geographic and topographic considerations and of historical aerometric data, the 4 study communities were expected to exhibit a gradient of long-term exposure to ambient sulfur oxide air pollution.

Parents of children in 14 elementary schools (4 in Ogden and Salt Lake City, 3 in Kearns and Magna) participated in the survey. Information on the presence and duration of cough and phlegm from the chest, other respiratory symptoms, tobacco smoking habits, and other covariates was collected from these parents by a standardized self-administered questionnaire that was based on the British Medical Research Council's Questionnaire on Respiratory Symptoms. The youngest school child in each family was given a questionnaire to take home and was asked to return the completed form to the school. The mother or female guardian was asked to complete the questionnaire whenever possible.

Questionnaires from families residing more than 2 miles from their community's air monitoring station were excluded from data analysis. After editing, the questionnaires were optically scanned to prepare a master file. The Dodge-Romig quality control technique (8) was then applied with stringency yielding a 90% probability that 98% or more of all questionnaires on the accepted master file would contain no errors. To determine whether self-selection might bias study results, a random sample of 100 families failing to return questionnaires was selected in each community. Study staff members telephoned these families to administer selected questions.

During 1971 and part of 1972, aerometric data were collected at a monitoring station on the roof of a school in each community. In 1972, all stations were resited to ground level, and measurements continued until the questionnaire survey. In all stations, 24-h gas bubblers were used to collect sulfur dioxide (SO_2) samples, and high-volume samplers were used to collect total suspended particulate (TSP) and water-soluble suspended sulfate (SS) and suspended nitrate (SN) samples.

Parents reporting cough and phlegm from the chest on most days or nights for as much

(Received in original form July 16, 1984 and in revised form March 21, 1985)

[1] From the Health Effects Research Laboratory, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina.

[2] Requests for reprints should be addressed to Dr. Robert S. Chapman, Mail Drop 58, Health Effects Research Laboratory, U. S. Environmental Protection Agency, Research Triangle Park, NC 27711.

as 3 months each year were considered to have persistent cough and phlegm (PCP). Mothers' and fathers' data were analyzed separately. Community- and smoking-specific prevalences of PCP were tabulated. Differences in PCP prevalence along the sulfur oxide pollution gradient were tested with chi-square statistics. These were computed for Magna versus the other communities combined in nonsmokers and ex-smokers together, and in all current smokers together.

Data were also analyzed by constructing categorical logistic regression models for mothers and fathers. These treated the presence or absence of PCP as the dependent variable and the following main effects and interactions as independent variables: (*1*) community—4 categories (1 for each community); (*2*) smoking habits—5 categories (nonsmoker, ex-smoker, smokes less than 1 pack, approximately 1 pack, and more than 1 pack of cigarettes per day); (*3*) age—2 categories (younger than or at least 40 yr of age); (*4*) education—3 categories (less than high school, high school graduate, more than high school); (*5*) occupational exposure to respiratory insult—2 categories for mothers (with and without such exposure), 3 for fathers (no exposure, as much as 5 yr of exposure, more than 5 yr of exposure); (*6*) length of residence in present community—4 categories (0–1, 2–5, 6–10, and at least 11 yr of residence); (*7*) interactions of the community main effect with each of the other main effects.

The significance levels of independent variables were determined by chi-square test statistics. The effect of community on prevalence was tested in 2 steps. The first was to generate a chi-square that assessed overall differences in prevalence among all 4 communities. The second was to partition this overall statistic into 2 chi-squares, one of which assessed the prevalence difference between Magna and the other 3 communities, the other of which assessed the prevalence difference among the other 3 communities. Because no interaction was significant at alpha = 0.05, a second regression model containing only the main effects described above was used to generate model-estimated PCP prevalences.

The results of the 1976 survey were compared with those of a similar prevalence survey conducted in 1970 in the same 4 communities (5). Persons living in their present community for less than 2 yr and persons with more than 5 yr of occupational exposure to respiratory irritants were excluded from this comparison, since these exclusions had previously been applied to the 1970 data.

Results

1976 Survey

Mean ambient air pollution concentrations in each study community from 1964 through 1975 are presented in table 1. The table shows a long-term sulfur oxide concentration gradient across the 4 communities. The mean SO_2 concentration was consistently lowest in Ogden and Salt Lake City, somewhat higher in Kearns, and distinctly highest in Magna. From 1971 through 1975, the range of annual mean SO_2 concentrations in Ogden overlapped that in Salt City, which in turn overlapped that in Kearns. However, the range in Magna did not overlap that in any other community. Mean concentrations of SS were distributed along the same ambient exposure gradient. From 1971 through 1975, annual intercommunity differences in mean TSP levels were small; in no year did the highest level exceed the lowest by over 36 $\mu g/m^3$. The annual mean SN concentration did not exceed 3.5 $\mu g/m^3$ in any community. Thus, no consistent intercommunity gradient of TSP or SN concentrations was observed.

The total enrollment in the 14 participating elementary schools was 7,532. The total number of questionnaires distributed, which approximated the number of families with children in these schools, was 4,606. Numbers and percentages of questionnaires returned in each community are presented in table 2, in which the questionnaires are also sorted by their acceptability for further analysis. Response rates were similar in all communities, averaging 79.5%. Over 91% of returned questionnaires had been completed in every community. The major reason for exclusion of returned questionnaires was residence more than 2 miles from an air monitoring station. After further exclusion of questionnaires with missing data, a total of 3,057 mothers and 2,566 fathers remained in the subject pool. Sex- and community-specific sample sizes for final analysis ranged from 447 (Ogden fathers) to 982 (Kearns mothers).

A total of 2,757 mothers and 2,312

TABLE 1

MEAN AMBIENT AIR POLLUTANT CONCENTRATIONS ($\mu g/m^3$) IN UTAH STUDY COMMUNITIES, 1964–1975

	1964–1967 (Estimated)	1968–1970 (Estimated)	1971–1975 (Measured)					
			1971	1972	1973	1974	1975	5-Yr Mean
Sulfur dioxide*								
Ogden	NA†	NA	9	12	13	10	12	11
Salt Lake City	17	18	15	18	27	12	17	18
Kearns	33	32	23	26	45	39	41	36
Magna	95	92	63	88	127	148	149	115
Total suspended particulates‡								
Ogden	108	88	66	77	56	47	43	56
Salt Lake City	103	84	71	86	68	70	50	68
Kearns	< 50	< 50	39	50	51	50	44	47
Magna	57	70	54	65	77	79	63	67
Suspended sulfates*								
Ogden	5.8	3.7	5.6	5.8	5.7	3.4	4.3	5.0
Salt Lake City	7.7	4.7	7.3	8.0	8.4	5.2	5.4	6.9
Kearns	8.7	8.6	7.9	8.2	9.9	6.8	6.7	7.9
Magna	15.3	15.0	12.5	12.8	16.8	13.6	13.7	13.9
Suspended nitrates*								
Ogden	NA	NA	2.8	2.3	1.9	1.7	3.5	2.4
Salt Lake City	NA	NA	3.3	2.7	1.8	2.3	3.3	2.7
Kearns	NA	NA	2.4	2.0	1.2	1.6	3.1	2.1
Magna	NA	NA	1.9	1.7	0.9	1.2	2.8	1.7

* Arithmetic means.

† Not available.

‡ Total suspended particulate levels from 1964 through 1970 and from 1971 through 1975 are presented as arithmetic and geometric means, respectively. (Arithmetic and geometric means from 1971 through 1975 differed by less than 2%.)

TABLE 2

1976 UTAH RESPIRATORY SYMPTOM SURVEY: RESPONSE RATES AND NUMBERS OF QUESTIONNAIRES USABLE FOR ANALYSIS BY COMMUNITY

	Ogden		S.L.C.		Kearns		Magna		All	
	(*n*)	(%)‡	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)	(*n*)	(%)
Number of questionnaires distributed	984	100.0	1,310	100.0	1,325	100.0	987	100.0	4,606	100.0
Questionnaires not returned*	173	17.6	293	22.4	285	21.5	192	19.5	943	20.5
Questionnaires returned†	811	82.4	1,017	77.6	1,040	78.5	795	80.5	3,663	79.5
Not usable for further analysis	239	24.3	51	3.9	20	1.5	138	14.0	448	9.7
Out of monitoring zone	230	23.4	36	2.7	10	0.8	133	13.5	409	8.9
Insufficient data	7	0.7	6	0.5	6	0.5	4	0.4	23	0.5
Duplicates	2	0.2	6	0.5	2	0.2	1	0.1	11	0.2
Itinerant families	0	—	3	0.2	0	—	0	—	3	0.1
Address unknown	0	—	0	—	2	0.2	0	—	2	0.0
Usable for further analysis	572	58.1	966	73.7	1,020	77.0	657	66.6	3,215	89.8

* Includes families not replying, families refusing to reply, and families returning blank questionnaires.
† Percentages of returned questionnaires that were completed were as follows: Ogden, 95.8%; Salt Lake City, 91.2%; Kearns, 96.4%; Magna, 95.1%.
‡ Percentage of questionnaires distributed.

fathers (90.2 and 90.1%, respectively) reported themselves as white. In Ogden, Salt Lake City, and Kearns, whites constituted an average of 89.9% of mothers and 89.6% of fathers. In Magna, 91.1% of mothers and fathers were white. In Ogden, Salt Lake City, and Kearns, an average of 73.8% of mothers and 60.1% of fathers was younger than 40 yr of age. In Magna, 73.6% of mothers and 60.7% of fathers were in this age group. The majority of mothers and fathers had graduated from high school but had not received further education. Educational attainment in both sexes tended to relate inversely to ambient community sulfur oxide level. In the whole study population, 37.7% of fathers and 26.9% of mothers were reported to be current smokers; there was little intercommunity difference in smoking habits. Educational attainment and tobacco consumption were strongly inversely related.

TABLE 3

1976 UTAH RESPIRATORY SYMPTOM SURVEY: CRUDE PREVALENCE (PERCENT) OF PERSISTENT COUGH AND PHLEGM BY AGE, ETHNIC GROUP, CIGARETTE SMOKING HISTORY, EDUCATION, OCCUPATIONAL EXPOSURE, AND LENGTH OF RESIDENCE IN PRESENT COMMUNITY

	Mothers			Fathers		
	Cases* (*n*)	Total in Group	Prevalence (%)	Cases (*n*)	Total in Group	Prevalence (%)
Age, yr						
< 30	56	812	6.9	29	375	7.7
30–39	85	1,439	5.9	118	1,183	10.0
40–49	41	671	6.1	73	705	10.4
> 49	9	135	6.7	27	303	8.9
Ethnic group						
White	174	2,757	6.3	228	2,312	9.9
Nonwhite	17	300	5.7	19	254	7.5
Smoking history						
Nonsmoker	48	1,905	2.5	35	1,024	3.4
Ex-smoker	9	331	2.7	26	575	4.5
Smokes < 1 pk	25	270	9.3	12	206	5.8
Smokes about 1 pk	48	361	13.3	72	433	16.6
Smokes > 1 pk	61	190	32.1	102	328	31.1
All smokers	134	821	16.3	186	967	19.2
Education						
< High School	75	733	10.2	83	511	16.2
High School	109	2,118	5.1	153	1,621	9.4
> High School	7	206	3.4	11	434	2.5
Occupational exposure						
None	159	2,803	5.7	112	1,605	7.0
5 yr or less	32†	254	12.6	46	366	12.6
> 5 yr	—	—	—	89	595	15.0
Years of residence in present community						
0–1	16	235	6.8	18	178	10.1
2–5	28	545	5.1	41	447	9.2
6–10	27	561	4.8	44	472	9.3
≥11	120	1,716	7.0	144	1,469	9.8

* Number of cases of persistent cough and phlegm, the numerator in the prevalence calculation.
† Due to small sample size, all mothers with occupational exposure are combined into one category.

A subject was considered to have had occupational exposure to respiratory irritants if he or she answered "yes" to the question, "At your job, are you now or have you been frequently exposed to irritating smoke, dust, or fumes?" The percentage of mothers reporting such exposure ranged from 6.8% in Kearns to 12.1% in Magna. The corresponding percentage of fathers ranged from 25.0% in Salt Lake City to 54.4% in Magna. Length of residence in present community tended to relate inversely to community sulfur oxide exposure.

Crude PCP prevalences by sex and by the covariates discussed above are presented in table 3. In each age group, prevalence was higher in fathers than in mothers, though sex-specific prevalence varied little with age or ethnic group. As expected, cigarette smoking was strongly associated with crude PCP prevalence, though little difference between lifetime nonsmokers and ex-smokers was observed in either sex. Crude prevalence varied inversely with educational attainment, probably, at least partly, because of the strong inverse relation between education and cigarette consumption. Crude prevalence varied directly with duration of occupational exposure to respiratory irritants. Prevalences were slightly lower in mothers and fathers residing 2 through 10 yr in their present community than in those residing there for a shorter or longer period.

TABLE 4

1976 UTAH RESPIRATORY SYMPTOM SURVEY: PREVALENCE (PERCENT) OF PERSISTENT COUGH AND PHLEGM BY SEX, COMMUNITY, AND CIGARETTE SMOKING HISTORY

	Lifetime Nonsmokers*			Ex-smokers*			Current Smokers†		
	Cases (*n*)	Total in Group	Prevalence (%)	Cases (*n*)	Total in Group	Prevalence (%)	Cases (*n*)	Total in Group	Prevalence (%)
Mothers									
Ogden	8	347	2.3	1	61	1.6	21	139	15.1
S.L.C.	12	528	2.3	3	108	2.8	39	263	14.8
Kearns	12	646	1.9	2	91	2.2	36	245	14.7
Magna	16	384	4.2	3	71	4.2	38	174	21.8
Fathers									
Ogden	6	176	3.4	4	107	3.7	39	164	23.8
S.L.C.	5	298	1.7	1	137	0.7	41	257	16.0
Kearns	8	344	2.3	11	214	5.1	58	330	17.6
Magna	16	206	7.8	10	117	8.5	48	216	22.2

* X^2 statistics for nonsmokers and ex-smokers, Magna versus other communities combined: mothers, $X^2 = 6.08$ ($p < 0.025$); fathers, $X^2 = 19.78$ ($p < 0.0005$).

† X^2 statistics for current smokers, Magna versus other communities combined: mothers, $X^2 = 4.92$ ($p < 0.05$); fathers, $X^2 = 1.60$ ($p > 0.20$).

TABLE 5

1976 UTAH RESPIRATORY SYMPTOM SURVEY: PREVALENCE (PERCENT) OF PERSISTENT COUGH AND PHLEGM IN CURRENT SMOKERS BY DAILY SMOKING HABITS

	Smokes < 1 Pack			Smokes About 1 Pack			Smokes > 1 Pack		
	Cases (*n*)	Total in Group	Prevalence (%)	Cases (*n*)	Total in Group	Prevalence (%)	Cases (*n*)	Total in Group	Prevalence (%)
Mothers									
Ogden	2	48	4.2	10	63	15.9	9	28	32.1
S.L.C.	9	98	9.2	8	107	7.5	22	58	37.9
Kearns	8	72	11.1	13	118	11.0	15	55	27.3
Magna	6	52	11.5	17	73	23.3	15	49	30.6
Fathers									
Ogden	5	39	12.8	13	71	18.3	21	54	38.9
S.L.C.	2	54	3.7	16	110	14.5	23	93	24.7
Kearns	2	66	3.0	24	160	15.0	32	104	30.8
Magna	3	47	6.4	19	92	20.7	26	77	33.8

The prevalence of PCP is presented by sex, community, and smoking habits in tables 4 and 5. Prevalences in nonsmoking and ex-smoking mothers were lowest in Ogden and highest in Magna. In smoking mothers as a whole, prevalence was highest in Magna and differed little among the other communities. In mothers who smoked more than a pack per day, prevalence was somewhat higher in Ogden and Salt Lake City than in Magna. Prevalences in nonsmoking and ex-smoking fathers were lowest in Salt Lake City and highest by a substantial margin in Magna. In smoking fathers, prevalence was generally highest in Ogden, and was higher in Magna than in Salt Lake City or Kearns. Intercommunity prevalence differences in smoking and nonsmoking mothers, and in nonsmoking fathers, were significant at alpha = 0.05. Thus, PCP prevalence was generally positively associated with long-term ambient community sulfur oxide exposure, more strongly in mothers than in fathers and more strongly in nonsmokers and ex-smokers than in current smokers.

Chi-square statistics and associated p values from the categorical logistic regression model are presented in table 6. In mothers, the overall modeled community effect on prevalence was marginally significant at alpha = 0.05 ($p = 0.055$). The difference in prevalence between Magna and the other 3 communities was significant ($p = 0.006$), and there was virtually no difference among the other communities ($p = 0.951$). Thus, the regression model yielded a clear association of persistent symptom prevalence with ambient sulfur oxide exposure in mothers.

In fathers, the overall modeled community effect on prevalence was significant ($p = 0.006$), as were the difference in prevalence between Magna and the other communities ($p = 0.027$) and the difference among the other communities ($p = 0.025$). The significant difference between Magna and the other communities suggested an association of prevalence with ambient sulfur oxide exposure in fathers. However, this association was attenuated by the similarity of p values for the comparisons of Magna to the other communities, and of the other communities to each other.

The effects of smoking habit and occupational exposure were significant in mothers and the effects of smoking habit, occupational exposure, and educational attainment were significant in fathers. The effect of residence length approached significance in mothers ($p = 0.094$) but not in fathers ($p = 0.896$). No other main effects and no interactions were significant in either sex.

Model-estimated PCP prevalences in mothers and fathers are presented in table 7. In computing estimated prevalences, the following level of each main effect was employed as a reference point: the average of Ogden, Salt Lake City, and Kearns; age younger than 40 yr; high school graduate; nonsmoker; no occupational exposure; residence of at least 11 yr in present community. The choice of reference point affects the magnitude of estimated rates, but it does not affect the differences among these rates across categories in any main effect. As expected,

TABLE 6

1976 UTAH RESPIRATORY SYMPTOM SURVEY: CATEGORICAL LOGISTIC REGRESSION ANALYSIS OF EFFECTS ON PERSISTENT SYMPTOM PREVALENCE: CHI-SQUARE STATISTICS AND p-VALUES ASSOCIATED WITH INDEPENDENT VARIABLES

Independent Variable Classification	Degrees of Freedom	Mothers		Fathers	
		X^2	p Value	X^2	p Value
Main effects					
Community	3	7.6	0.055	12.3	0.006
Magna vs others	1	7.5	0.006	4.9	0.027
Among others	2	0.1	0.951	7.4	0.025
Age	1	2.1	0.147	1.3	0.254
Education	2	0.4	0.819	14.9	< 0.001
Smoking	4	191.2	< 0.001	180.0	< 0.001
Occupational exposure	1 or 2*	11.0	< 0.001	13.1	0.001
Length of residence	3	6.4	0.094	0.6	0.896
Interactions of community with:					
Age	3	1.8	0.615	1.7	0.637
Education	6	9.2	0.163	4.5	0.609
Smoking	12	13.9	0.307	14.9	0.247
Occupational exposure	3 or 6†	2.2	0.532	9.6	0.143
Length of residence	9	10.3	0.327	4.6	0.868

* Occupational exposure has 1 df for mothers, 2 df for fathers.
† The interaction of community with occupational exposure has 3 df for mothers, 6 df for fathers.

versely associated with education even after adjustment for the other main effects.

Comparison of 1976 Survey to 1970 Survey

In table 1, most of the mean pollution concentrations for 1964 through 1970 are based on estimates rather than on direct measurements (9), so the figures presented for these years should not be considered quantitative. The table suggests, however, that from 1964 through 1975, SO_2 and SS concentrations were considerably higher in Magna than in the other 3 communities, and thus that the intercommunity gradient of ambient sulfur oxide exposure in the half-decade preceding the 1970 survey was at least qualitatively similar to that in the half-decade preceding the 1976 survey. The table also suggests that ambient sulfur oxide concentrations in the study communities did not change greatly between the 1960s and the first half of the 1970s.

Prevalences of persistent cough and phlegm in 1970 and 1976 are presented by sex, community, and smoking habits in table 8. The 2 surveys yielded similar results in all smoking-sex groups but smoking fathers, in whom reported prevalence was highest in Magna in 1970 and highest by a slight margin in Ogden in 1976. On balance, an association of persistent cough and phlegm prevalence with ambient sulfur oxide exposure was observed in both surveys, though more consistently in 1970 than in 1976.

TABLE 7

1976 UTAH RESPIRATORY SYMPTOM SURVEY: MODEL-ESTIMATED PREVALENCE OF PERSISTENT COUGH AND PHLEGM IN CATEGORIES OF EACH MAIN EFFECT*

	Estimated Prevalence (%)	
	Mothers	Fathers
Community		
Odgen	2.1	3.8
S.L.C.	2.2	2.1
Kearns	2.1	2.5
Magna	3.5	3.7
Age, yr		
< 40	2.1	2.7
≥ 40	2.8	3.2
Education		
< High school	2.4	4.0
High school	2.1	2.7
> High school	2.2	1.2
Smoking history		
Nonsmoker	2.1	2.7
Ex-smoker	2.3	2.8
Smokes < 1 pk	7.9	3.5
Smokes 1 pk	12.1	10.9
Smokes > 1 pk	28.9	21.5
Occupational exposure		
None	2.1	2.7
< 5 yr	4.6	4.0
> 5 yr	—†	4.7
Years of residence in present community		
0–1	1.7	3.4
2–5	1.4	2.8
6–10	1.3	2.8
≥11	2.1	2.7

* Prevalences were adjusted to the following baseline levels: The average of Ogden, Salt Lake City, and Kearns; younger than 40 yr of age; high school graduate; nonsmoker; no occupational exposure; residence of 11 yr or more in present community.
† Because of small sample size, all mothers with occupational exposure are included in one category.

estimated prevalence differed most across smoking categories. In smokers, the model estimated a strong monotonic relationship between prevalence and daily cigarette consumption.

Model-estimated prevalences in mothers were just above 2.0% in Ogden, Salt Lake City, and Kearns, and rose to 3.5% in Magna. In fathers, modeled prevalences in Ogden and Magna were higher than in Salt Lake City and Kearns. Occupational exposure was directly associated with modeled prevalence in both sexes. Estimated prevalences were slightly higher in older than in younger mothers and fathers. Estimated prevalence in mothers varied little with education; in fathers, prevalence remained in-

Discussion

In the 1976 survey, elevated PCP prevalence was associated with a 5-yr mean ambient SO_2 concentration of approximately 115 $\mu g/m^3$ (with annual means ranging from approximately 60 to 150 $\mu g/m^3$), coupled with a 5-yr mean sus-

TABLE 8

PREVALENCE (PERCENT) OF PERSISTENT COUGH AND PHLEGM IN 1970 AND 1976 BY SEX, COMMUNITY, AND CIGARETTE SMOKING HISTORY*

	Nonsmokers		Ex-Smokers		Current Smokers	
	1970	1976	1970	1976	1970	1976
Mothers						
Ogden	2.3	2.8	5.3	2.6	17.8	15.0
S.L.C.	2.0	1.7	4.0	1.2	14.7	12.4
Kearns	4.7	2.0	7.0	2.7	15.3	16.0
Magna	5.2	4.0	7.1	4.3	22.2	24.6
Fathers						
Ogden	3.0	2.0	2.6	2.6	19.9	21.8
S.L.C.	3.6	1.3	3.4	1.0	18.6	16.7
Kearns	2.3	1.9	5.4	5.7	20.1	17.1
Magna	6.8	7.9	6.0	8.3	26.8	21.0

* Persons living less than 2 yr in their present community were excluded, as were persons reporting occupational exposure for more than 5 yr to coal dust, cutting oils, asbestos, mine dust, smelter fumes, raw cotton dust, or foundry dust.

pended sulfate concentration of approximately 13.9 $\mu g/m^3$ (with annual means ranging from 12.5 to 16.8 $\mu g/m^3$). This association was more consistent in mothers than in fathers and more consistent in nonsmokers and ex-smokers than in current smokers. The results of the survey were consistent with those of the 1970 survey in the same communities and with previous surveys in other areas (10–12).

As expected, the model-estimated effect of cigarette smoking on PCP prevalence was larger than that of any other class of independent variables considered. That the estimated smoking effect increased monotonically with cigarette consumption enhances confidence in the model employed. The increment in prevalence rates estimated across communities was about 10% as large as across smoking categories and about 60% as large as across occupational exposure categories.

Persistent cough and phlegm prevalence rates have been reported for each sex separately. In statistical analysis of 1976 results, prevalence was adjusted for age, cigarette smoking habits, educational attainment, occupational exposure to respiratory irritants, and length of residence in present community. Thus, it is unlikely that the observed association between ambient sulfur oxide exposure and prevalence in 1976 arose spuriously from uneven distribution of any of these covariates across communities. It was judged unnecessary to adjust for ethnic group in statistical analysis, because over 90% of the study sample was white, since whites and nonwhites were very similarly distributed along the pollution gradient, and since crude prevalence rates were similar in whites and nonwhites.

The accuracy with which fixed-station aerometric measurements reflect subjects, true ambient pollution exposures is likely to decrease with increasing distance between a subject's residence and station. It was therefore judged necessary to maximize the number of subjects living near their community's station. Random sampling would not have fulfilled this requirement as effectively as did the school-based sampling design employed. Under this design the 1976 sample was confined to young adults, 67.7% of whom were younger than 40 yr of age. The results reported here cannot be applied to other age groups. At the same time, response rates were similarly high in all communities, and the analysis included a large number of subjects. The only restrictions imposed by the study design and analysis plan were that participants had children in participating elementary schools, that they lived within 2 miles of their community's aerometric station, and that they supplied sufficient questionnaire information. Thus, we believe that the survey sample yielded good representation of young adults in the study area.

It was possible to contact 106 nonrespondent mothers and 90 nonrespondent fathers. Assuming that each of the 943 unreturned questionnaires represented missing information from both a mother and a father, these figures imply contact rates of 11.2% in mothers and 9.5% in fathers. Application of sex- and community-specific prevalence rates in contacted nonrespondents to estimated total numbers of nonrespondents, and subsequent addition of the numbers of cases thus generated to numbers of cases observed among respondents in each community, yielded the following crude prevalence estimates in respondents and nonrespondents together: mothers—Ogden, 4.2%; Salt Lake City, 7.1%; Kearns, 3.9%; Magna, 8.2%; fathers—Ogden, 7.9%; Salt Lake City, 8.7%; Kearns, 7.8%; Magna, 12.0%. Thus, though the number of contacted nonrespondents was too small to yield a conclusive test for nonresponse bias, it appears unlikely that such bias materially affected the results reported here.

From 1971 through 1975, both the EPA and the state of Utah measured ambient SO_2 concentrations on the same school grounds in Magna. Five-year mean SO_2 concentrations measured by EPA and the state were, respectively, 115 $\mu g/m^3$ and 120 $\mu g/m^3$ (13). Four-year mean TSP concentrations, measured by EPA and the state of Utah from 1972 through 1975, were 71 and 76 $\mu g/m^3$, respectively. Thus, there was good agreement between side-by-side pollution measurements in the study community nearest to the copper smelter.

The extent to which the reported ambient pollution measurements represented subjects' actual exposures depends on the amount of time they spent both indoors and away from their communities' immediate air monitoring zones. Indoor pollution concentrations, which depend on such factors as domestic tobacco smoking, building ventilation, and heating and cooking fuels, often differ from outdoor concentrations. Also, a portion of study participants may routinely have spent time outside their community's two-mile monitoring zone. In this survey, indoor pollution was not measured, nor were subjects' activity patterns determined. Thus it is not possible to conclude what effects these factors may have exerted on study results.

In smoking fathers, the association of PCP prevalence with sulfur oxide exposure was stronger in 1970 than in 1976. At least 3 factors may have contributed to this change. First, smokers' daily cigarette consumption may have differed between the 2 surveys. Individual daily consumption data in 1970 are no longer available, so the effect of this factor cannot be quantitated. Second, though aerometric figures do not suggest reductions in long-term ambient sulfur oxide levels between the 2 surveys, improvements in other unmeasured environmental factors may have contributed to reductions in prevalence in Magna.

Third, chance variation may well have contributed to this change. Because mothers were asked to provide both parents' information whenever possible, fathers' prevalence was subject to more such variation than was mothers'. The exact proportion of fathers not providing their own information is not known. However, a second questionnaire was distributed to 10% of study participants approximately 1 month after the 1976 survey. With respect to presence or absence of PCP, the 2 questionnaires showed discordant results in only 9 (2.7%) of 329 mothers, and in 25 (9.2%) of 273 fathers (chi-square = 11.59, $p < 0.005$). The observed stability of mothers' prevalence rates enhances confidence in the dependent variable employed, and in the observed association of PCP with sulfur oxide exposure in mothers.

The clinical significance of persistent cough and phlegm as measured in questionnaire surveys remains uncertain. At the least, these symptoms produce discomfort and anxiety. In the absence of physiologic tests, it cannot be stated whether they were accompanied by accelerated loss of mechanical lung function.

In the late 1970s, furnaces were replaced and advanced pollution control devices were installed at the copper smelter. Utah state aerometric data for Magna suggest that reductions in ambient sulfur oxide levels accompanied these changes. A follow-up prevalence survey would be useful to test further the observed association of PCP prevalence with elevated ambient sulfur oxide exposure, and to assess the reversibility

of persistent cough and phlegm as reported in field survey questionnaires. Such a follow-up should include as many 1976 survey participants as possible and should measure the covariates discussed above. Determination of domestic fuels used by subjects since childhood would be useful, as would description of subjects' activity patterns. Indoor air monitoring in subjects' homes and workplaces would be desirable. Ascertainment of subjects' acute respiratory illness histories and surveillance of acute respiratory infection in the study communities might sharpen the interpretation of findings (14–17). Lung function tests would also provide useful information.

Acknowledgment

The writers gratefully acknowledge the essential contribution made by the state of Utah Department of Health, in particular Dr. J. Wanless Southwick and the members of the field study staff.

References

1. Firket M. Sur les causes des accidents survenus dans la vallée de la Meuse lors des brouillards de Decembre, 1930. Bull Acad R Med Belg 1931, Vol 11:683–739.

2. Morbidity and mortality during the London fog of December 1952. Reports of Public Health Medical Service, no. 95. London: H.M. Stationery Office, 1954.

3. Sheppard D, Wong WS, Uehara CF, Nadel JA, Boushey HA. Lower threshold and greater bronchomotor responsiveness of asthmatic subjects to sulfur dioxide. Am Rev Respir Dis 1980; 122: 873–8.

4. Sheppard D, Saisho A, Nadel JA, Boushey HA. Exercise increases sulfur dioxide-induced bronchoconstriction in asthmatic subjects. Am Rev Respir Dis 1981; 123:486–91.

5. House DE, Finklea JF, Shy CM, *et al.* Prevalence of chronic respiratory disease symptoms in adults: 1970 survey of Salt Lake Basin communities. Health consequences of sulfur oxides. A report from CHESS, 1970–1971. Washington, D.C.: USGPO, 1974 (EPA publication no. 650/1-74-004).

6. Chapman RS, Shy CM, Finklea JF, House DE, Goldberg HE, Hayes CG. Chronic respiratory disease in military inductees and parents of schoolchildren. Arch Environ Health 1973; 27:138–42.

7. An analysis of the CHESS health effects studies. Section VI. The Environmental Protection Agency's Research Program with Primary Emphasis on the Community Health and Environmental Surveillance System (CHESS): an investigative report. Prepared for Committee on Science and Technology, U.S. House of Representatives. Washington, D.C.: USGPO, 1976; 57–80 (U.S. Government document no. 77-590).

8. Dodge HF, Romig HG. Sampling inspection tables single and double Sampling. New York: John Wiley and Sons, 1956:71.

9. Hertz MB, Truppi LA, English TD, *et al.* Human exposure to air pollutants in Salt Lake Basin communities, 1940–1971. Health consequences of sulfur oxides. A report from CHESS, 1970–1971. Washington, D.C., USGPO, 1974 (EPA publication no. 650/1-74-004; 2-3 through 2-39).

10. Hayes CG, Hammer DI, Shy CM, *et al.* Prevalence of chronic respiratory disease symptoms in adults: 1970 survey of 5 Rocky Mountain communities. ibid., pp. 3-19 through 3-34.

11. Finklea JF, Goldberg J, Hasselblad V, Shy CM, Hayes CG. Prevalence of chronic respiratory disease symptoms in military recruits: Chicago Induction Center, 1969–1970. ibid., pp. 4-23 through 4-36.

12. Goldberg HE, Finklea JF, Nelson CJ, et al. Prevalence of chronic respiratory disease symptoms in adults: 1970 survey of New York communities. ibid., pp. 3-19 through 3-34.

13. Utah State Health Department Aerometric Measurements, contained on the Storage and Retrieval of Aerometric Data (SAROAD) File, Station No. 460520001F02, 1971–1975.

14. Nelson WC, Finklea JF, House DE, Calafiore DC, Hertz MB, Swanson DH. Frequency of acute lower respiratory disease in children: retrospective survey of Salt Lake Basin communities, 1967–1970. Health consequences of sulfur oxides. A report from CHESS, 1970–1971. Washington, DC: USGPO, 1974 (EPA publication no. 650/1-74-004; 2-55 through 2-74).

15. Love GJ, Cohen AA, Finklea JF, *et al.* Prospective surveys of acute respiratory disease in volunteer families: 1970–1971 New York studies. ibid., pp. 5-49 through 5-70.

16. Lebowitz MD, Burrows B. The relationship of acute respiratory illness history to the prevalence and incidence of obstructive lung disorders. Am J Epidemiol 1977; 105:544–54.

17. Burrows B, Knudson RJ, Lebowitz MD. The relationship of childhood respiratory illness to adult obstructive airway disease. Am Rev Respir Dis 1977; 115:751–60.